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research division

EXECUTIVE SUMMARY

FEASIBILITY OF NON-CONTACT MEASUREMENT OF FUEL CHANNEL ELONGATION AT DARLINGTON NGS 'A'

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An investigation of a non-contact dimensional measuring device was conducted. A non-contact STEM prototype using an ultrasonic distance measuring instrument was built, and tested during a planned outage at Pickering Unit 7 on May 17, 1986. These measurements were compared with measurements done by the standard mechanical S.T.E.M. and the largest difference was within the specified accuracy requirement.

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ontario hydro
research division

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FEASIBILITY OF NON-CONTACT MEASUREMENT OF FUEL CHANNEL ELONGATION AT DARLINGTON NGS 'A'

W.K. Chan and E. de Buda

An investigation of a non-contact dimensional measuring device was conducted. A non-contact STEM prototype using an ultrasonic distance measuring instrument was built, and tested during a planned outage at Pickering Unit 7 on May 17, 1986. These measurements were compared with measurements done by the standard mechanical S.T.E.M. and the larget difference was within the specified accuracy requirements.

1.0 INTRODUCTION

A Scanning Tool for Elongation Measurement (S.T.E.M.) will be required to periodically monitor the growth of the pressure tubes (P/T) at Darlington NGS "A" as it is now done at Pickering and Bruce. Unlike the Bruce S.T.E.M. devices, which are permanently mounted on each fuelling machine bridge carriage, the Darlington S.T.E.M. design will be based on the Pickering F/M snout-mounted concept.

The existing Pickering S.T.E.M devices have been successfully used for a number of pressure tube elongation measurements. The portable snout-mounted S.T.E.M. system permits simple installation, easier maintenance, and requires only small amounts of personnel radiation exposure, while providing adequate measurement accuracy.

The Metallurgical Research Department, Nondestructive and Fracture Evaluation Section, was requested to investigate the possibility of developing a non-contact S.T.E.M device for Darlington NGS "A". This report reviews the feasibility of the non-contact measurement concept and presents the test results of a prototype Ultrasonic STEM system trial during a planned outage at Pickering unit 7 on May 17, 1986.

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2.0 CONTACT VS. NON-CONTACT STEM

The mechanical contact STEM devices now in use at Pickering and Bruce make use of a stainless steel wheel, which rolls over the endfittings, while its motion is monitored by a displacement transducer/1/2/3/. The measurement of the wheel deflection represents the distance from the end of each endfitting to a plane defined by the bridge carriage system. At the end of each row, the wheel must be retracted before the fuelling machine bridge is moved vertically, otherwise damage can occur to both the measurement device and the endfittings. This requires the incorporation of an extend/retract mechanism which can at times be subject to mechanical malfunction. At Bruce A, where STEM devices are permanently mounted on the bridge, some of the STEM devices failed to operate due to radiation damage in the insulating material of the electrical wires and in the plastic components/6/. Being permanently mounted made maintenance much more difficult and therefore the portable snout-mounted method was chosen for Darlington STEM. A non-contact and snout-mounted measuring instrument that can operate at a distance would eliminate these difficulties. In addition, while the mechanical contact STEM is limited to measuring endfittings only, it is conceivable that a non-contact STEM could also be used for measuring the distance to the yoke studs. If this is feasible, it could eliminate the large amount of man-rem expenditure required to do the stud measurements required in the pressure tube/calandria tube elongation monitoring program.

3.0 NON-CONTACT DIMENSIONAL MEASURING DEVICES

A preliminary investigation of non-contact dimensional measuring devices has been conducted and has been previously reported/4/5/. Among the different devices considered were optical imaging, interferometry, acoustics, eddy current, and microwave. Details of these methods can be found in reference 5. While each of these devices present their own unique technical limitations in terms of dimensional and environmental constraints, the major limitations are in range, resolution and stability. In comparison to the Pickering mechanical contact S.T.E.M. concept, the non-contact measuring method for Darlington NGS is likely to be cost effective and reliable.

4.0 PROTOTYPE SEARCH

A preliminary product investigation revealed that a commercially available ultrasonic distance measuring device (Ultrasonic Arrays model DMS1000) could be used for the pressure tube elongation measurement and thereby replace the mechanical contact STEM device. This device known as a capacitive transducer uses two conductive materials (a metallic backing disk and the metallized film surface) separated by a dielectric, and generates an ultrasonic pulse by applying a time varying voltage to a metallized film. The transducer emits the ultrasonic pulse which is reflected back from a reference bar as well as from the target object. The same transducer detects the return echoes and a digital processing unit converts the resulting time delays into a distance measurement. The reference bar provides for automatic calibration to overcome the effects of measurement inaccuracy due to environmental conditions which affect the speed of sound (humidity and temperature in particular). The distance between the endfitting and the fuelling machine snout is approximately 166 mm. It was felt, because of the relatively short signal path, that the pressure tube elongation measurement could achieve the

required accuracy (±1 mm) ,however, some questions were raised regarding the possibility of convection currents interfering with the measurement. A DMS1000 on loan for evaluation purposes showed promise, but the only sure test was an actual reactor face measurement scan.

5.0 A PROTOTYPE MEASURING HEAD

To resolve a number of uncertainties, a prototype enclosing a DMS1000 ultrasonic distance measuring transducer was built, and tested in a planned outage at Pickering unit 7 on May 17, 1986.

The body of the prototype had the same shape as the end of a Pickering endfitting to allow it to be clamped in the fuelling machine snout. The scan of the reactor face was carried out in a manner similar to that used for the mechanical contact STEM system. As shown in Figures 1, 2 and 3, the transducer (38 mm dia x 114 mm lg) was partially enclosed in the stainless steel measurement head body. The reference bar was surrounded by a metal hood which protected it from being damaged. The ultrasonic transducer was electrically connected to its control unit which was temporarily attached to the fuelling machine. Station wiring was used to convey the measurement data in RS-232 format to a microcomputer (Hyperion PC) in the control room which stored the data on floppy disk.

Rows X, U, L and G on the reactor east face were selected and measured both by the Pickering mechanical contact STEM as well as the Ultrasonic non-contact measuring head. Row X contains the dummy endfittings which were used as reference channels.

6.0 TEST RESULTS

The scan data for both contact and non-contact measurements were analyzed and compared (Graphs 1-5) to assess the non-contact method. Graphs 1-5 show the measured distances for the endfittings on each row from the scan plane. Tables 1-5 indicate the overall differences between two sets of the data with respect to their datum channels (dummy endfittings on row X). Generally there was very good agreement between the two measurements for the 4 rows scanned. The analyses indicated that the data for the rows X, U and L in both tests were practically the same (approx. 0.1 mm difference). For the data at row G, the direct mathematic differences, which ranged from 0.1 to 0.45, appeared to be somewhat larger than those of the other rows. This small (0.1 -0.45 mm) offset raised questions about whether this measurement offset would be larger for the upper rows due to air convection currents generated along the reactor face. Another possibility is that the data from mechanical STEM measurement on row G is offset due to an unknown cause.

7.0 SUMMARY AND CONCLUSIONS

Although the Pickering mechanical contact STEM has been successfully used for Pressure tube elongation measurement at Pickering NGS "B", some of the inherent operational limitations have led to an investigation of non-contact STEM methods. A prototype using an ultrasonic measuring device (Ultrasonic Arrays DMS1000) was built, and tested in Pickering NGS B Unit 7 on May 17, 1986. The prototype demonstrated its capability in this in-situ test and the test results indicated that it

could provide adequate accuracy for the P/T elongation measurement at Darlington. Small offsets between the contact and non-contact STEM measurements on row G raised a concern about the potential problem of air convection on the higher rows, although the error was still within limits.

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2. Dolbey, M.P. "Development of a Scanning Tool for Elongation Measurement for Pickering NGS", Ontario Hydro Research Report No. 77-455-H.

3. de Buda, E., "Development of a Scanning Tool for Elongation Measurement for Pickering NGS 'B'", Ontario Hydro Research Report No. 82-89-K.

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5. de Buda, E., "A Feasibility Study of Non-Contact Methods for the Measurement of Fuel Channel Elongation and Endshield Separation", Ontario Hydro Research Div. Report No. B80-153-K.

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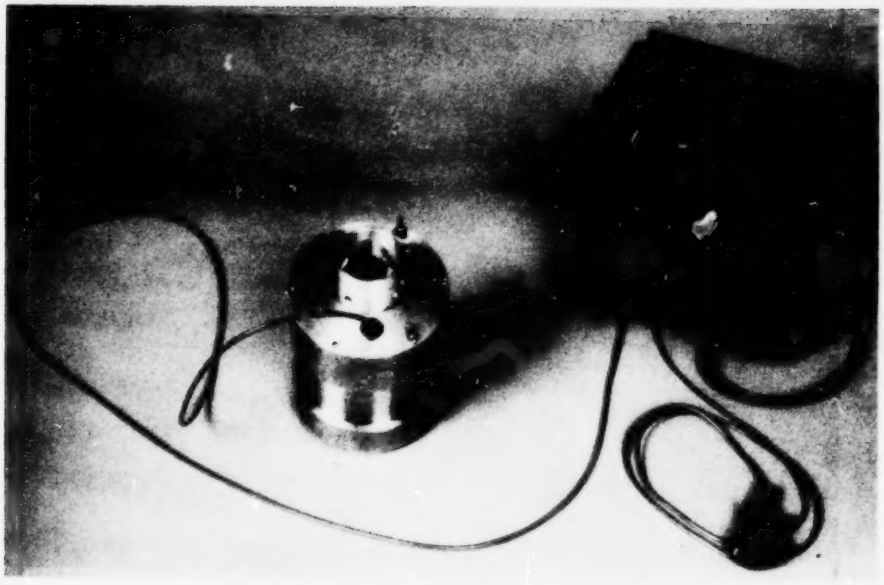


Figure 1: Ultrasonic Inspection System

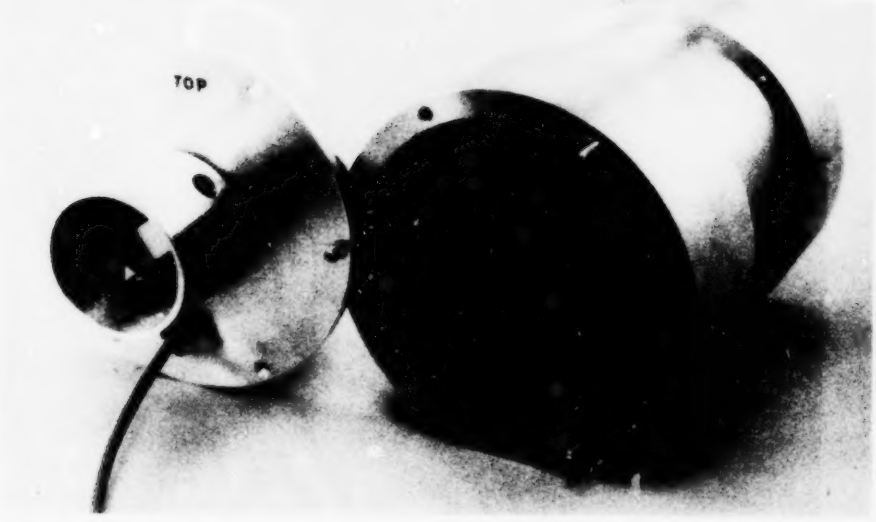


Figure 2: UT Measuring Head

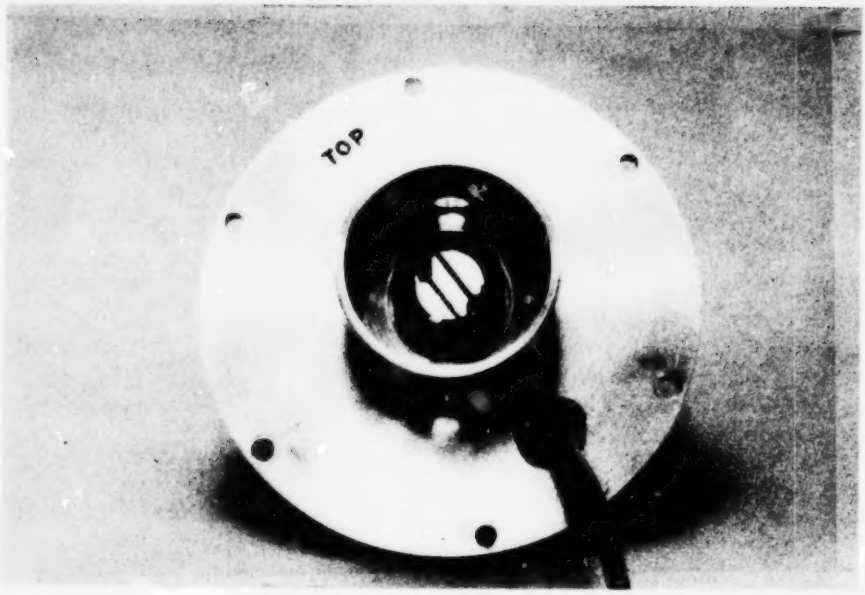
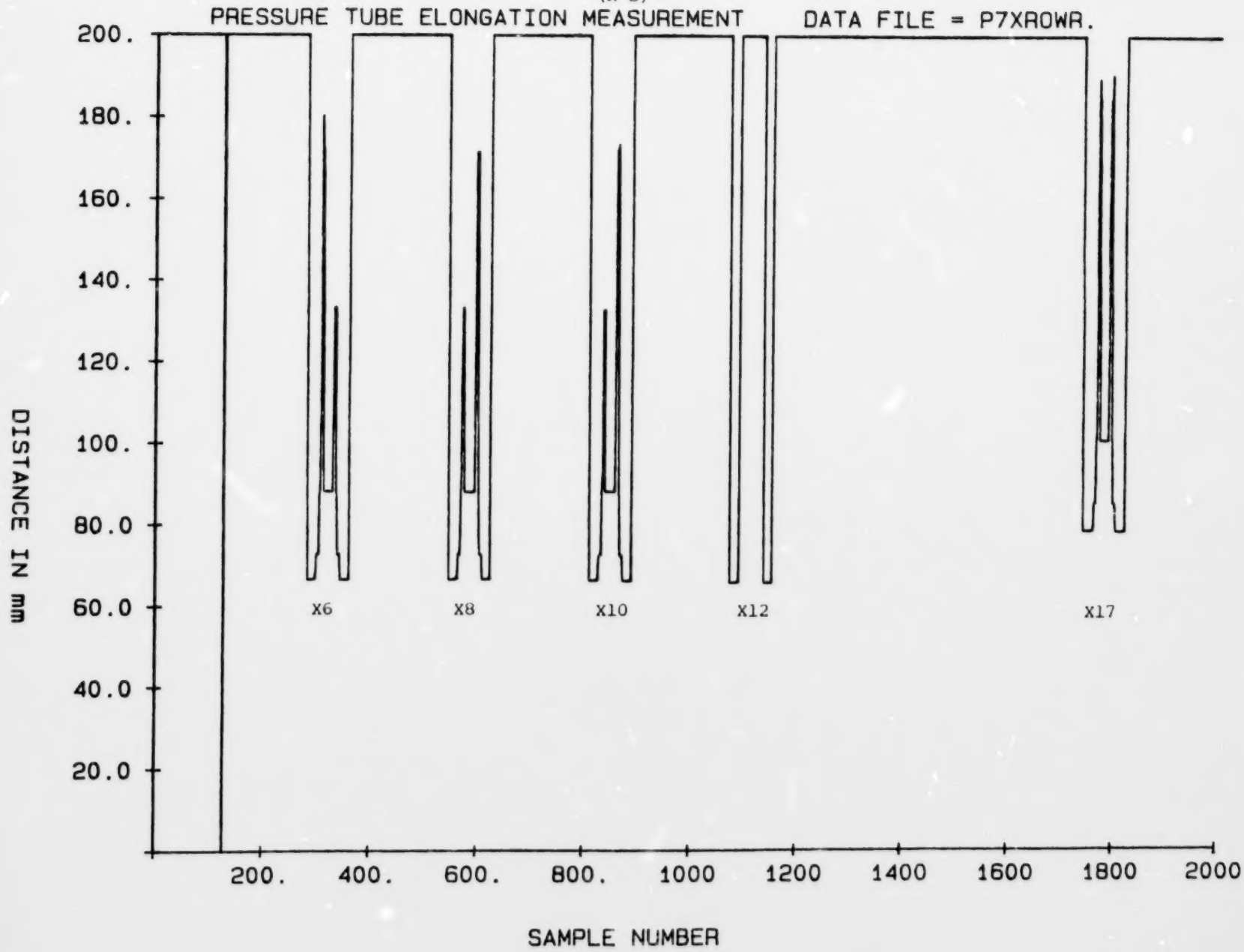


Figure 3: DMS1000 Distance Measuring Transducer

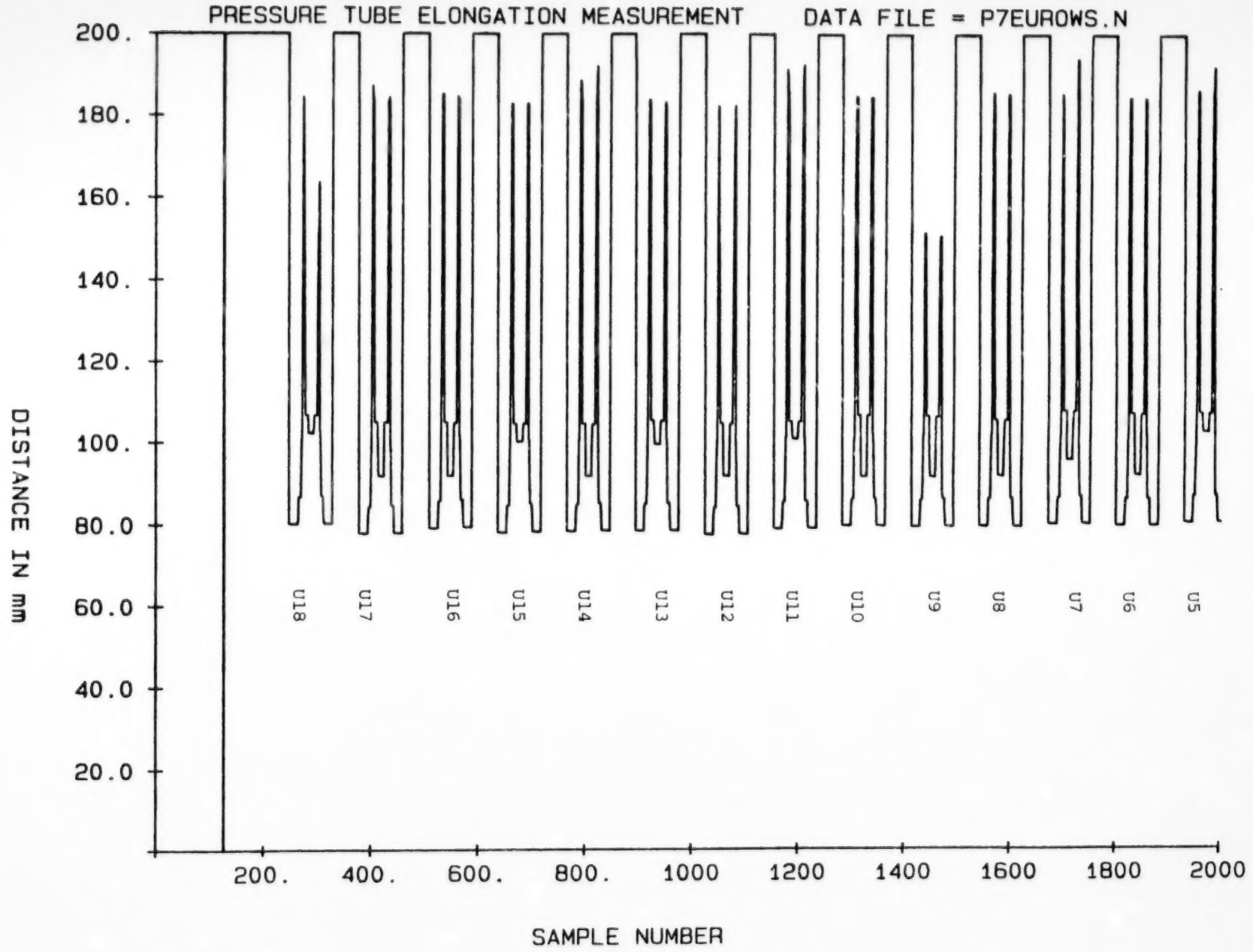
Graph 1

X Row Scan
(N-S)



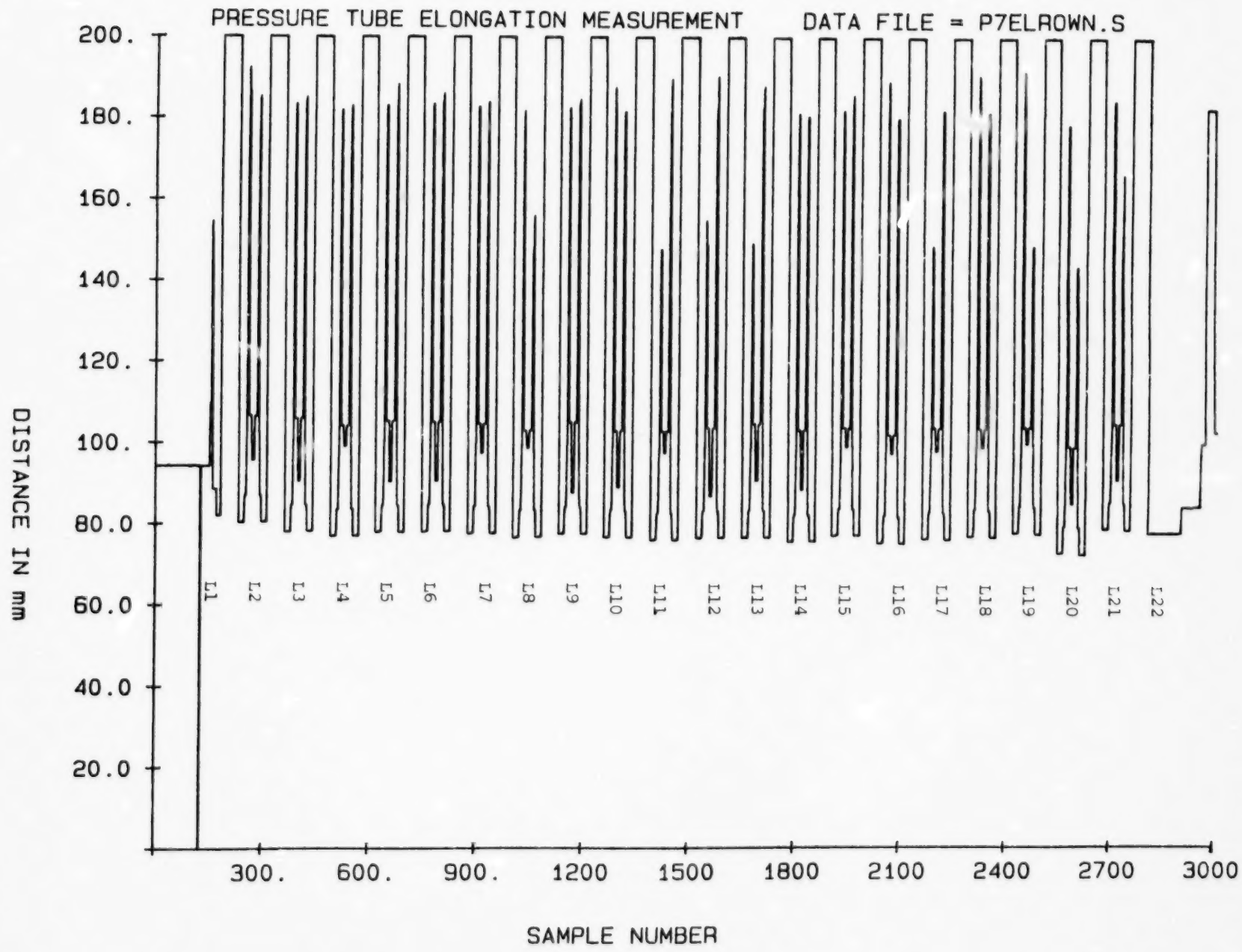
Graph 2

U Row Scan
(S-N)



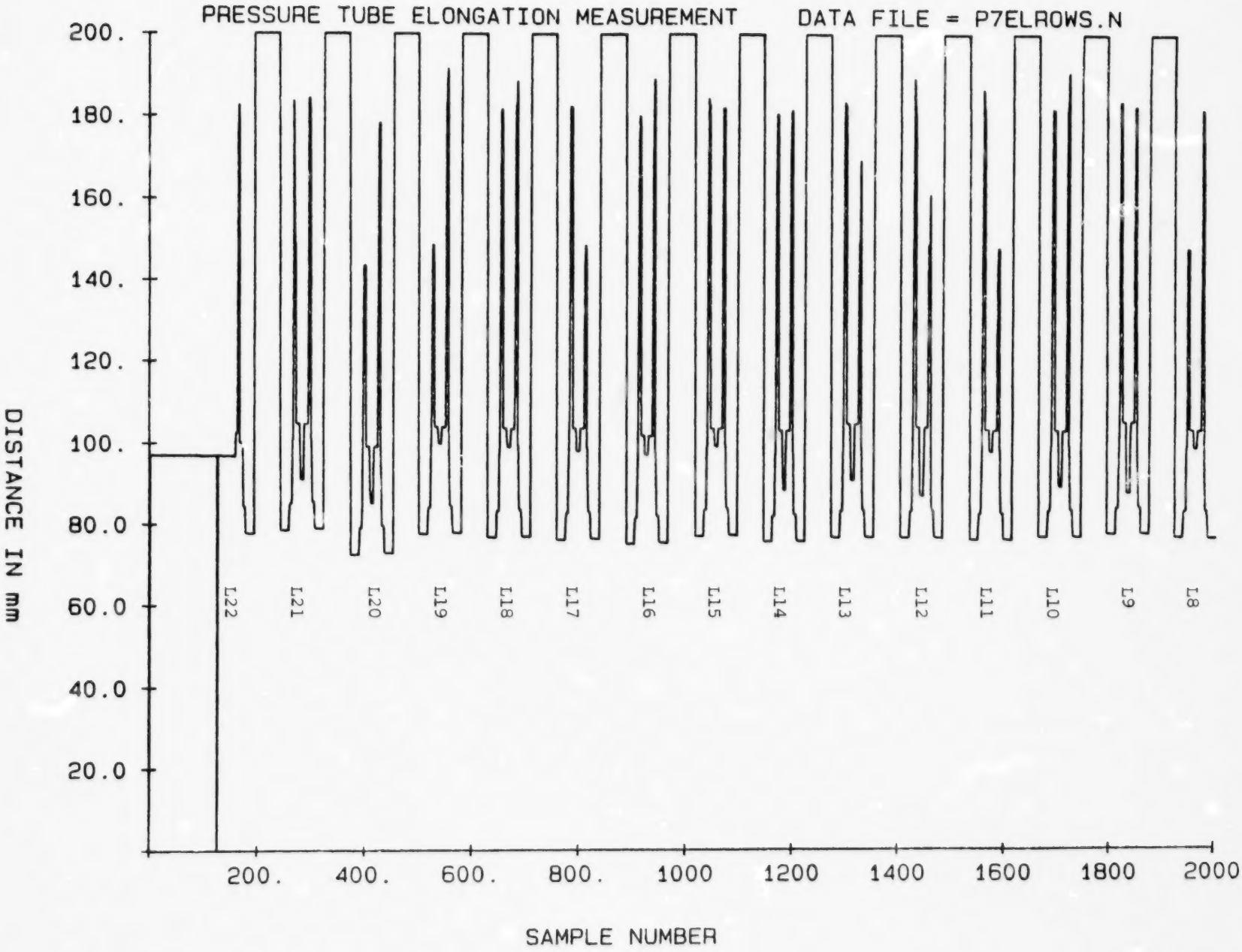
Graph 3

L Row Scan
(N-S)



Graph 4

L Row Scan
(S-N)



Graph 5

G Row Scan
(N-S)

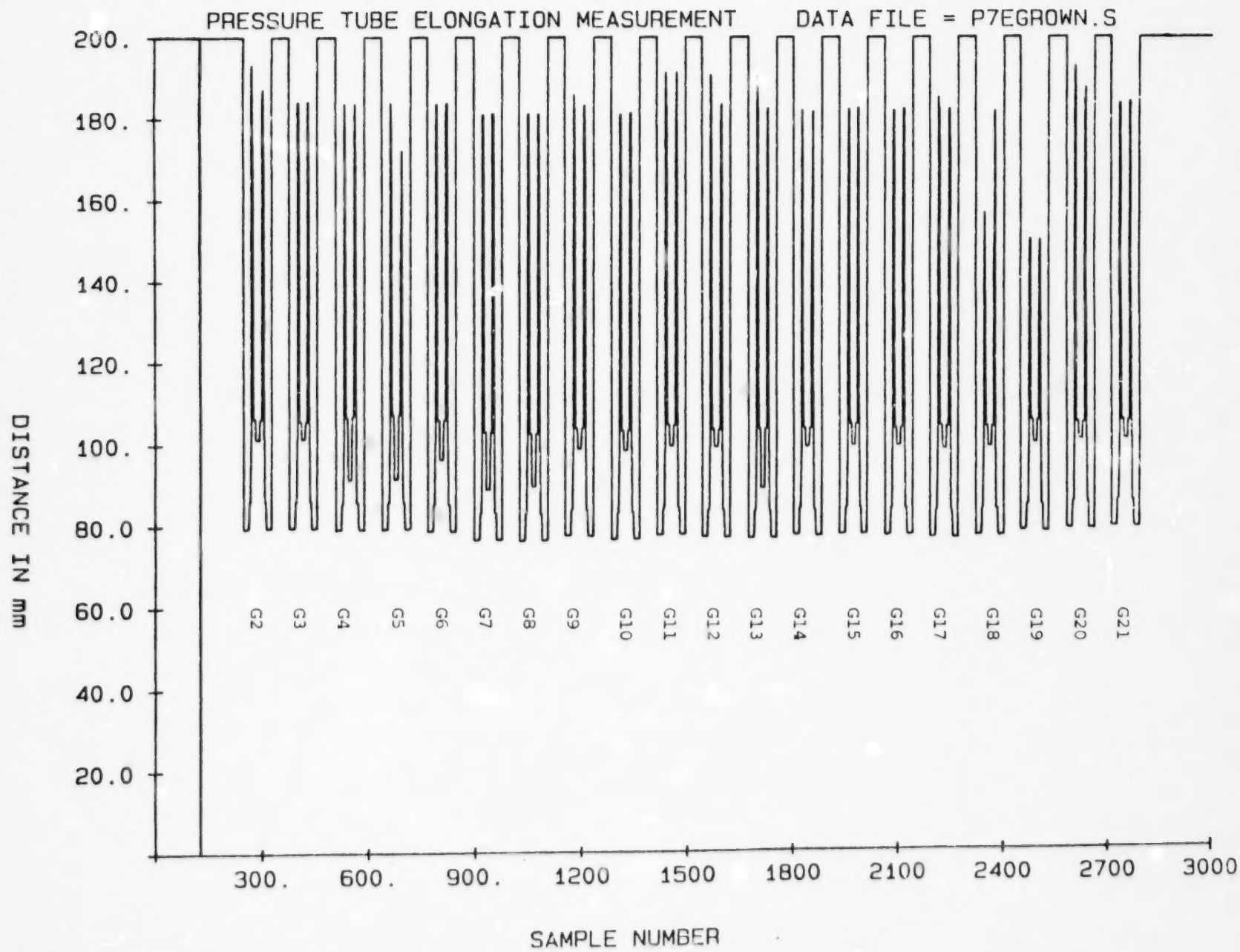


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TABLE 1

DISTANCE MEASUREMENT : REFERENCE ENFITTING P7XROW N-S
Fuel Channel# X6 X8 X10 X12 X17

R1: MEASURED BY THE UT DEVICE
R2: MEASURED BY THE CONTACT WHEEL STEM
DIF= R1-R2
DEV= DIF-AVG (AVG:AVERAGE VALUE OF DIFs)

X	R1 mm	R2 mm	DIF mm	AVG mm	DEV mm
6	66.70	27.50	39.20	39.12	0.08
6	66.67	27.50	39.17	39.12	0.05
8	66.62	27.50	39.12	39.12	0.00
8	66.65	27.50	39.15	39.12	0.03
10	66.31	27.20	39.11	39.12	-0.01
10	66.23	27.10	39.13	39.12	0.01
12	65.85	26.70	39.15	39.12	0.03
12	65.84	26.70	39.14	39.12	0.02
17	78.49	39.50	38.99	39.12	-0.13
17	78.33	39.30	39.03	39.12	-0.09

TABLE 2

DISTANCE MEASUREMENT : P7EUROW S-N U18 - U5

R1(Reference)/D1(Data) : UT SCAN
R2(Reference)/D2(Data) : CONTACT WHEEL STEM
DIF1=D1-R1/DIF2=D2-R2/DIF=DIF1-DIF2

U	R1 mm	D1 mm	R2 mm	D2 mm	DIF1 mm	DIF2 mm	DIF mm
18	65.84	80.22	26.70	40.90	14.38	14.20	0.18
18	65.84	80.21	26.70	41.00	14.37	14.30	0.07
17	65.84	77.81	26.70	38.60	11.97	11.90	0.07
17	65.84	77.94	26.70	38.70	12.10	12.00	0.10
16	65.84	79.04	26.70	39.90	13.20	13.20	0.00
16	65.84	79.32	26.70	40.10	13.48	13.40	0.08
15	65.84	78.01	26.70	38.80	12.17	12.10	0.07
15	65.84	78.24	26.70	39.00	12.40	12.30	0.10
14	65.84	78.29	26.70	39.10	12.45	12.40	0.05
14	65.84	78.50	26.70	39.20	12.66	12.50	0.16
13	65.84	78.46	26.70	39.20	12.62	12.50	0.12
13	65.84	78.50	26.70	39.30	12.66	12.60	0.06
12	65.84	77.59	26.70	38.30	11.75	11.60	0.15
12	65.84	77.71	26.70	38.50	11.87	11.80	0.07
11	65.84	79.00	26.70	39.80	13.16	13.10	0.06
11	65.84	79.13	26.70	39.90	13.29	13.20	0.09
10	65.84	79.73	26.70	40.50	13.89	13.80	0.09
10	65.84	79.72	26.70	40.50	13.88	13.80	0.08
9	65.84	79.58	26.70	40.30	13.74	13.60	0.14
9	65.84	79.62	26.70	40.40	13.78	13.70	0.08
8	65.84	79.66	26.70	40.50	13.82	13.80	0.02
8	65.84	79.59	26.70	40.50	13.75	13.80	-0.05
7	65.84	80.24	26.70	41.00	14.40	14.30	0.10
7	65.84	80.23	26.70	41.10	14.39	14.40	-0.01
6	65.84	79.97	26.70	40.70	14.13	14.00	0.13
6	65.84	79.86	26.70	40.70	14.02	14.00	0.02
5	65.84	80.61	26.70	41.40	14.77	14.70	0.07
5	65.84	80.63	26.70	41.40	14.79	14.70	0.09

TABLE 3

DISTANCE MEASUREMENT : P7ELROW N-S L22 - L1

R1(Reference)/D1(Data): UT SCAN
R2(Reference)/D2(Data): CONTACT WHEEL STEM
DIF1=D1-R1 / DIF2=D2-R2 / DIF=DIF1-DIF2

L	R1 mm	D1 mm	R2 mm	D2 mm	DIF1 mm	DIF2 mm	DIF mm
1	65.84	81.95	26.70	42.80	16.11	16.10	0.01
2	65.84	80.39	26.70	41.30	14.55	14.60	-0.05
2	65.84	80.54	26.70	41.50	14.70	14.80	-0.10
3	65.84	78.06	26.70	38.90	12.22	12.20	0.02
3	65.84	78.30	26.70	39.20	12.46	12.50	-0.04
4	65.84	77.08	26.70	37.90	11.24	11.20	0.04
4	65.84	77.13	26.70	38.00	11.29	11.30	-0.01
5	65.84	78.07	26.70	38.90	12.23	12.20	0.03
5	65.84	78.00	26.70	38.90	12.16	12.20	-0.04
6	65.84	78.15	26.70	39.10	12.31	12.40	-0.09
6	65.84	78.22	26.70	39.10	12.38	12.40	-0.02
7	65.84	77.71	26.70	38.60	11.87	11.90	-0.03
7	65.84	77.78	26.70	38.60	11.94	11.90	0.04
8	65.84	76.74	26.70	37.60	10.90	10.90	0.00
8	65.84	76.84	26.70	37.70	11.00	11.00	0.00
9	65.84	77.68	26.70	38.60	11.84	11.90	-0.06
9	65.84	77.66	26.70	38.50	11.82	11.80	0.02
10	65.84	76.79	26.70	37.70	10.95	11.00	-0.05
10	65.84	76.74	26.70	37.60	10.90	10.90	0.00
11	65.84	76.09	26.70	37.00	10.25	10.30	-0.05
11	65.84	76.07	26.70	37.00	10.23	10.30	-0.07
12	65.84	76.59	26.70	37.50	10.75	10.80	-0.05
12	65.84	76.63	26.70	37.50	10.79	10.80	-0.01
13	65.84	76.66	26.70	37.70	10.82	11.00	-0.18
13	65.84	76.70	26.70	37.70	10.86	11.00	-0.14
14	65.84	75.72	26.70	36.60	9.88	9.90	-0.02
14	65.84	75.75	26.70	36.60	9.91	9.90	0.01
15	65.84	77.15	26.70	38.20	11.31	11.50	-0.19
15	65.84	77.18	26.70	38.00	11.34	11.30	0.04
16	65.84	75.33	26.70	36.30	9.49	9.60	-0.11
16	65.84	75.23	26.70	36.10	9.39	9.40	-0.01
17	65.84	76.30	26.70	37.30	10.46	10.60	-0.14
17	65.84	76.11	26.70	37.00	10.27	10.30	-0.03
18	65.84	76.88	26.70	37.80	11.04	11.10	-0.06
18	65.84	76.73	26.70	37.60	10.89	10.90	-0.01
19	65.84	77.82	26.70	38.70	11.98	12.00	-0.02
19	65.84	77.56	26.70	38.40	11.72	11.70	0.02
20	65.84	72.92	26.70	33.70	7.08	7.00	0.08
20	65.84	72.49	26.70	33.30	6.65	6.60	0.05
21	65.84	78.86	26.70	39.80	13.02	13.10	-0.08
21	65.84	78.61	26.70	39.30	12.77	12.60	0.17
22	65.84	77.79	26.70	38.60	11.95	11.90	0.05

TABLE 4

DISTANCE MEASUREMENT : P7ELROW N-S & P7ELROW S-N

ULTRASONIC SCAN : F/M OFFSET CHECK
R1(Reference)/DATA : D1 (N-S) & D2 (S-N)
DIF1=D1-R1 / DIF2=D2-R1 / DIF=DIF1-DIF2

L	R1 mm	D1 mm	D2 mm	DIF1 mm	DIF2 mm	DIF mm
22	65.84	77.79	77.75	11.95	11.91	0.04
21	65.84	78.61	78.59	12.77	12.75	0.02
21	65.84	78.86	78.94	13.02	13.10	-0.08
20	65.84	72.49	72.56	6.65	6.72	-0.07
20	65.84	72.92	72.96	7.08	7.12	-0.04
19	65.84	77.56	77.61	11.72	11.77	-0.05
19	65.84	77.82	77.83	11.98	11.99	-0.01
18	65.84	76.73	76.75	10.89	10.91	-0.02
18	65.84	76.88	76.92	11.04	11.08	-0.04
17	65.84	76.11	76.15	10.27	10.31	-0.04
17	65.84	76.30	76.35	10.46	10.51	-0.05
16	65.84	75.23	75.14	9.39	9.30	0.09
16	65.84	75.33	75.42	9.49	9.58	-0.09
15	65.84	77.18	77.06	11.34	11.22	0.12
15	65.84	77.15	77.26	11.31	11.42	-0.11
14	65.84	75.75	75.78	9.91	9.94	-0.03
14	65.84	75.72	75.77	9.88	9.93	-0.05
13	65.84	76.70	76.69	10.86	10.85	0.01
13	65.84	76.66	76.76	10.82	10.92	-0.10
12	65.84	76.63	76.70	10.79	10.86	-0.07
12	65.84	76.59	76.62	10.75	10.78	-0.03
11	65.84	76.07	76.15	10.23	10.31	-0.08
11	65.84	76.09	76.14	10.25	10.30	-0.05
10	65.84	76.74	76.82	10.90	10.98	-0.08
10	65.84	76.79	76.85	10.95	11.01	-0.06
9	65.84	77.66	77.65	11.82	11.81	0.01
9	65.84	77.68	77.68	11.84	11.84	0.00
8	65.84	76.84	76.79	11.00	10.95	0.05
8	65.84	76.74	76.58	10.90	10.74	0.16
7	65.84	77.78	77.55	11.94	11.71	0.23
7	65.84	77.71	77.56	11.87	11.72	0.15
6	65.84	78.22	78.15	12.38	12.31	0.07
6	65.84	78.15	78.12	12.31	12.28	0.03
5	65.84	78.00	77.96	12.16	12.12	0.04
5	65.84	78.07	78.02	12.23	12.18	0.05

TABLE 5

DISTANCE MEASUREMENT : P7EGROW N-S G2 - G21

R1(Reference)/D1(Data)/DIF1=D1-R1 : UT SCAN
R2(Reference)/D2(Data)/DIF2=D2-R2 : CONTACT WHEEL STEM
DIF=DIF1-DIF2

G	R1 mm	D1 mm	R2 mm	D2 mm	DIF1 mm	DIF2 mm	DIF mm
2	65.84	79.27	26.70	40.50	13.43	13.80	-0.37
2	65.84	79.53	26.70	40.80	13.69	14.10	-0.41
3	65.84	79.55	26.70	40.80	13.71	14.10	-0.39
3	65.84	79.62	26.70	40.80	13.78	14.10	-0.32
4	65.84	79.14	26.70	40.10	13.30	13.40	-0.10
4	65.84	79.10	26.70	40.40	13.26	13.70	-0.44
5	65.84	79.20	26.70	40.30	13.36	13.60	-0.24
5	65.84	79.11	26.70	40.40	13.27	13.70	-0.43
6	65.84	78.68	26.70	39.80	12.84	13.10	-0.26
6	65.84	78.58	26.70	39.80	12.74	13.10	-0.36
7	65.84	76.45	26.70	37.60	10.61	10.90	-0.29
7	65.84	76.59	26.70	37.70	10.75	11.00	-0.25
8	65.84	76.27	26.70	37.40	10.43	10.70	-0.27
8	65.84	76.32	26.70	37.40	10.48	10.70	-0.22
9	65.84	77.54	26.70	38.60	11.70	11.90	-0.20
9	65.84	77.30	26.70	38.60	11.46	11.90	-0.44
10	65.84	76.50	26.70	37.60	10.66	10.90	-0.24
10	65.84	76.62	26.70	37.70	10.78	11.00	-0.22
11	65.84	77.52	26.70	38.70	11.68	12.00	-0.32
11	65.84	77.66	26.70	38.80	11.82	12.10	-0.28
12	65.84	77.11	26.70	38.20	11.27	11.50	-0.23
12	65.84	77.00	26.70	38.00	11.16	11.30	-0.14
13	65.84	76.76	26.70	37.80	10.92	11.10	-0.18
13	65.84	76.79	26.70	37.80	10.95	11.10	-0.15
14	65.84	77.54	26.70	38.60	11.70	11.90	-0.20
14	65.84	77.31	26.70	38.40	11.47	11.70	-0.23
15	65.84	77.68	26.70	38.80	11.84	12.10	-0.26
15	65.84	77.80	26.70	38.80	11.96	12.10	-0.14
16	65.84	77.40	26.70	38.50	11.56	11.80	-0.24
16	65.84	77.54	26.70	38.60	11.70	11.90	-0.20
17	65.84	76.88	26.70	37.90	11.04	11.20	-0.16
17	65.84	76.66	26.70	37.90	10.82	11.20	-0.38
18	65.84	77.25	26.70	38.40	11.41	11.70	-0.29
18	65.84	77.20	26.70	38.40	11.36	11.70	-0.34
19	65.84	78.51	26.70	39.60	12.67	12.90	-0.23
19	65.84	78.22	26.70	39.40	12.38	12.70	-0.32
20	65.84	78.89	26.70	40.20	13.05	13.50	-0.45
20	65.84	78.86	26.70	40.00	13.02	13.30	-0.28
21	65.84	79.41	26.70	40.60	13.57	13.90	-0.33
21	65.84	79.28	26.70	40.40	13.44	13.70	-0.26

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